

What is claimed is:

1. An exercise load intensity evaluation device comprising:

an ejection duration measurement section which noninvasively measures cardiac  
5 ejection duration of a subject during exercise; and

an ejection duration change detection section which detects a change in the  
ejection duration which is measured at each measurement time by the ejection duration  
measurement section and is input to the ejection duration change detection section.

10 2. The exercise load intensity evaluation device as defined in claim 1, further  
comprising:

an exercise load intensity measurement section which measures exercise load  
intensity of the subject,

wherein the ejection duration change detection section detects a change in the  
15 ejection duration corresponding to different degrees of exercise load intensity based on  
output from the exercise load intensity measurement section.

3. The exercise load intensity evaluation device as defined in claim 1,

wherein the ejection duration measurement section includes an  
20 electrocardiogram measurement section which measures an electrocardiogram of the  
subject during exercise, and measures the ejection duration from a feature of the  
electrocardiogram which reflects the cardiac ejection duration.

4. The exercise load intensity evaluation device as defined in claim 1,

25 wherein the ejection duration measurement section includes a pulse wave  
detection section which is attached to the subject during exercise and noninvasively  
detects a peripheral pulse wave, and measures the ejection duration from a feature of the

pulse wave which reflects the cardiac ejection duration.

5. The exercise load intensity evaluation device as defined in claim 1,

wherein the ejection duration measurement section includes:

5 a pulse wave detection section which is attached to the subject during exercise and noninvasively detects a peripheral pulse wave; and

an ejection duration correction section which corrects the cardiac ejection duration based on output from the pulse wave detection section.

10 6. The exercise load intensity evaluation device as defined in claim 4,

wherein the ejection duration measurement section further includes:

a body movement waveform detection section which detects a body movement waveform according to body movement of the subject during exercise; and

15 a body movement waveform removal section which removes the body movement waveform detected by the body movement waveform detection section from the pulse wave detected by the pulse wave detection section, and

wherein the ejection duration measurement section measures the ejection duration based on the pulse wave from which the body movement waveform has been removed.

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7. The exercise load intensity evaluation device as defined in claim 4,

wherein the ejection duration measurement section measures a time interval from rise of the pulse wave to a dicrotic notch.

25 8. The exercise load intensity evaluation device as defined in claim 4,

wherein the ejection duration measurement section includes a first differentiation section which differentiates the pulse wave; and a second differentiation

section which differentiates the pulse wave differentiated by the first differentiation section, and measures the ejection duration based on the pulse wave differentiated by the second differentiation section.

5           9. The exercise load intensity evaluation device as defined in claim 4,  
          wherein the ejection duration measurement section includes a comparator which compares a wave height of the pulse wave with a reference value, and measures the ejection duration based on a pulse width of a rectangular wave output from the comparator.

10           10. The exercise load intensity evaluation device as defined in claim 9,  
          wherein the comparator is a comparator with hysteresis and having a positive input terminal which is connected with a feed back resistor.

15           11. The exercise load intensity evaluation device as defined in claim 4,  
          wherein the ejection duration measurement section further includes a Fourier transformation section which transforms the pulse wave detected by the pulse wave detection section,

          wherein the ejection duration measurement section extracts a frequency  
20   spectrum which is obtained based on the feature of the pulse wave which reflects the cardiac ejection duration from Fourier transformed frequency spectra, and

          wherein the ejection duration change detection section detects a change in frequency of the frequency spectrum extracted at each measurement time by the ejection duration measurement section.

25           12. The exercise load intensity evaluation device as defined in claim 6,  
          wherein the ejection duration measurement section further includes:

a first Fourier transformation section which transforms the pulse wave detected by the pulse wave detection section; and

a second Fourier transformation section which transforms the body movement waveform detected by the body movement waveform detection section, and

5        wherein the body movement waveform removal section subtracts frequency spectra at the same frequency among frequency spectra in each frequency band output from the first and second Fourier transformation sections.

13. The exercise load intensity evaluation device as defined in claim 12,

10        wherein the ejection duration measurement section extracts a frequency spectrum which is obtained based on the feature of the pulse wave which reflects the cardiac ejection duration from frequency spectra output from the body movement waveform removal section, and

15        wherein the ejection duration change detection section detects a change in frequency of the frequency spectrum extracted at each measurement time by the ejection duration measurement section.

14. The exercise load intensity evaluation device as defined in claim 12,

20        wherein the ejection duration measurement section includes an inverse Fourier transformation section which performs inverse Fourier transformation of output from the body movement waveform removal section; a first differentiation section which differentiates the pulse wave which has been inverse-Fourier-transformed; and a second differentiation section which differentiates the pulse wave differentiated by the first differentiation section, and measures the ejection duration based on the pulse wave  
25        differentiated by the second differentiation section.

15. The exercise load intensity evaluation device as defined in claim 1, further

comprising:

a notification section which notifies the subject when the exercise load intensity exceeds a lactate threshold based on output from the ejection duration change detection section.

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16. The exercise load intensity evaluation device as defined in claim 1, further comprising:

a notification section which notifies the subject when the exercise enters anaerobic exercise based on output from the ejection duration change detection section.

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17. An exercise load intensity evaluation device comprising:

an ejection duration measurement section which noninvasively measures cardiac ejection duration of a subject during exercise;

a storage section which stores correlation data between the ejection duration or a heart rate corresponding to one cycle of a heartbeat at the ejection duration and exercise load intensity; and

an exercise load intensity detection section which detects the exercise load intensity from the storage section based on the ejection duration measured by the ejection duration measurement section.

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18. The exercise load intensity evaluation device as defined in claim 17, further comprising:

an ejection duration change detection section which detects a change in the ejection duration which is measured at each measurement time by the ejection duration measurement section and is input to the ejection duration change detection section,

wherein the exercise load intensity detection section detects the exercise load intensity when the ejection duration change detection section detects that the ejection

duration is changed.

19. The exercise load intensity evaluation device as defined in claim 1,  
wherein a ratio of the ejection duration to one cycle of a heartbeat is used as an  
5 index instead of the ejection duration.

20. The exercise load intensity evaluation device as defined in claim 1,  
wherein the ejection duration change detection section outputs one cycle of a  
heartbeat when the ejection duration changes.

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21. The exercise load intensity evaluation device as defined in claim 15,  
wherein the notification section includes a storage section which stores the  
ejection duration exceeding a safe exercise range, and notifies the subject that the  
exercise load intensity is out of the safe exercise range when the measured ejection  
15 duration is smaller than the ejection duration stored in the storage section.

22. Exercise equipment comprising the exercise load intensity evaluation device  
as defined in claim 1.

20 23. The exercise equipment as defined in claim 22,  
wherein a range of the exercise load intensity is set as a range of a heart rate  
based on one cycle of a heartbeat output from the ejection duration change detection  
section.

25 24. The exercise equipment as defined in claim 22, further comprising:  
an output section which outputs exercise menus of different degrees of exercise  
load intensity.

25. The exercise equipment as defined in claim 22, further comprising:  
a load output section which outputs exercise load which is applied to the subject according to an exercise menu at different degrees of exercise load intensity.

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26. The exercise equipment as defined in claim 24,  
wherein each of the exercise menus is set in a predetermined exercise load intensity range based on a lactate threshold calculated for the subject from a correlation between the exercise load intensity and the ejection duration.

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27. The exercise equipment as defined in claim 26, further comprising:  
a storage medium which stores the exercise menus and is removable from the exercise equipment.

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28. An exercise load intensity evaluation device comprising:  
a diastolic time measurement section which noninvasively measures cardiac diastolic time of a subject during exercise; and  
a diastolic time change detection section which detects a change in the diastolic time which is measured at each measurement time by the diastolic time measurement section and is input to the diastolic time change detection section.

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29. The exercise load intensity evaluation device as defined in claim 28, further comprising:

an exercise load intensity measurement section which measures exercise load intensity of the subject,

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wherein the diastolic time change detection section detects a change in the diastolic time corresponding to different degrees of exercise load intensity based on

output from the exercise load intensity measurement section.

30. The exercise load intensity evaluation device as defined in claim 28,  
wherein the diastolic time measurement section includes an electrocardiogram  
5 measurement section which measures an electrocardiogram of the subject during  
exercise, and measures the diastolic time from a feature of the electrocardiogram which  
reflects the cardiac diastolic time.

31. The exercise load intensity evaluation device as defined in claim 28,  
10 wherein the diastolic time measurement section includes a pulse wave detection  
section which is attached to the subject during exercise and noninvasively detects a  
peripheral pulse wave, and measures the diastolic time from a feature of the pulse wave  
which reflects the cardiac diastolic time.

15 32. The exercise load intensity evaluation device as defined in claim 28,  
wherein the diastolic time measurement section includes:  
a pulse wave detection section which is attached to the subject during exercise  
and noninvasively detects a peripheral pulse wave; and  
a diastolic time correction section which corrects the cardiac diastolic time based  
20 on output from the pulse wave detection section.

33. The exercise load intensity evaluation device as defined in claim 31,  
wherein the diastolic time measurement section further includes:  
a body movement waveform detection section which detects a body movement  
25 waveform according to body movement of the subject during exercise; and  
a body movement waveform removal section which removes the body  
movement waveform detected by the body movement waveform detection section from

the pulse wave detected by the pulse wave detection section, and

wherein the diastolic time measurement section measures the diastolic time based on the pulse wave from which the body movement waveform has been removed.

5           34. The exercise load intensity evaluation device as defined in claim 31,

wherein the diastolic time measurement section measures the diastolic time by subtracting ejection duration from rise of the pulse wave to a diastolic notch from one cycle of the pulse wave.

10           35. The exercise load intensity evaluation device as defined in claim 31,

wherein the diastolic time measurement section includes a first differentiation section which differentiates the pulse wave; and a second differentiation section which differentiates the pulse wave differentiated by the first differentiation section, and measures the diastolic time based on the pulse wave differentiated by the second  
15 differentiation section.

36. The exercise load intensity evaluation device as defined in claim 31,

wherein the diastolic time measurement section includes a comparator which compares a wave height of the pulse wave with a reference value, measures cardiac  
20 ejection duration based on a pulse width of a rectangular wave output from the comparator, and measures the diastolic time by subtracting the ejection duration from one cycle of the pulse wave.

37. The exercise load intensity evaluation device as defined in claim 36,

25           wherein the comparator is a comparator with hysteresis and having a positive input terminal which is connected with a feed back resistor.

38. The exercise load intensity evaluation device as defined in claim 31,  
wherein the diastolic time measurement section further includes a Fourier transformation section which transforms the pulse wave detected by the pulse wave detection section,

5        wherein the diastolic time measurement section extracts a frequency spectrum which is obtained based on the feature of the pulse wave which reflects the cardiac diastolic time from Fourier transformed frequency spectra, and

      wherein the diastolic time change detection section detects a change in frequency of the frequency spectrum extracted at each measurement time by the  
10       diastolic time measurement section.

39. The exercise load intensity evaluation device as defined in claim 33,

      wherein the diastolic time measurement section further includes:

      a first Fourier transformation section which transforms the pulse wave detected  
15       by the pulse wave detection section; and

      a second Fourier transformation section which transforms the body movement waveform detected by the body movement waveform detection section, and

      wherein the body movement waveform removal section subtracts frequency spectra at the same frequency among frequency spectra in each frequency band output  
20       from the first and second Fourier transformation sections.

40. The exercise load intensity evaluation device as defined in claim 39,

      wherein the diastolic time measurement section extracts a frequency spectrum which is obtained based on the feature of the pulse wave which reflects the cardiac  
25       diastolic time from frequency spectra output from the body movement waveform removal section, and

      wherein the diastolic time change detection section detects a change in

frequency of the frequency spectrum extracted at each measurement time by the diastolic time measurement section.

41. The exercise load intensity evaluation device as defined in claim 39,

5        wherein the diastolic time measurement section includes an inverse Fourier transformation section which performs inverse Fourier transformation of output from the body movement waveform removal section; a first differentiation section which differentiates the pulse wave which has been inverse-Fourier-transformed; and a second differentiation section which differentiates the pulse wave differentiated by the first  
10      differentiation section, and measures the diastolic time based on the pulse wave differentiated by the second differentiation section.

42. The exercise load intensity evaluation device as defined in claim 28, further comprising:

15        a notification section which notifies the subject when the exercise load intensity exceeds a lactate threshold based on output from the diastolic time change detection section.

43. The exercise load intensity evaluation device as defined in claim 28, further  
20      comprising:

      a notification section which notifies the subject when the exercise enters anaerobic exercise based on output from the diastolic time change detection section.

44. An exercise load intensity evaluation device comprising:

25        a diastolic time measurement section which noninvasively measures cardiac diastolic time of a subject during exercise;

      a storage section which stores correlation data between the diastolic time and

exercise load intensity; and

an exercise load intensity detection section which detects the exercise load intensity from the storage section based on the diastolic time measured by the diastolic time measurement section.

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45. The exercise load intensity evaluation device as defined in claim 44, further comprising:

a diastolic time change detection section which detects a change in the diastolic time which is measured at each measurement time by the diastolic time measurement  
10 section and is input to the diastolic time change detection section,

wherein the exercise load intensity detection section detects the exercise load intensity when the diastolic time change detection section detects that the diastolic time is changed.

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46. The exercise load intensity evaluation device as defined in claim 28,

wherein a ratio of the diastolic time to one cycle of a heartbeat is used as an index instead of the diastolic time.

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47. The exercise load intensity evaluation device as defined in claim 28,

wherein the diastolic time change detection section outputs one cycle of a heartbeat when the diastolic time changes.

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48. The exercise load intensity evaluation device as defined in claim 42,

wherein the notification section includes a storage section which stores the diastolic time exceeding a safe exercise range, and notifies the subject that the exercise load intensity is out of the safe exercise range when the measured diastolic time is smaller than the diastolic time stored in the storage section.

49. Exercise equipment comprising the exercise load intensity evaluation device as defined in claim 28.

5        50. The exercise equipment as defined in claim 49,  
wherein a range of the exercise load intensity is set as a range of a heart rate based on one cycle of a heartbeat output from the diastolic time change detection section.

10       51. The exercise equipment as defined in claim 49, further comprising:  
an output section which outputs exercise menus of different degrees of exercise load intensity.

15       52. The exercise equipment as defined in claim 49, further comprising:  
a load output section which outputs exercise load which is applied to the subject according to an exercise menu at different degrees of exercise load intensity.

20       53. The exercise equipment as defined in claim 51,  
wherein each of the exercise menus is set in a predetermined exercise load intensity range based on a lactate threshold calculated for the subject from a correlation between the exercise load intensity and the diastolic time.

25       54. The exercise equipment as defined in claim 53,  
wherein a storage medium which stores the exercise menus is removable from the exercise equipment.